ACTA Geographica Szegediensis *Tomus XXXI. 1993. pp. 71-82.*

First results of GIS based geoecological mapping

Dr. Gábor Mezősi - Dr. Ilona Bárány-Kevei - Dr. László Mucsi - Dr. Imre Balogh

INTRODUCTION

The increasing stress on the geographical environment, its changing conditions, quality and potentials has drawn attention to the importance of the internal relationships within the geoecological system. This can be investigated from three distinctive points of view:

- an approach with a biological (ecological) aim, where the biotic factors of the environment or the structure itself are emphasized,
- a geographical approach, where the investigation concentrates on abiotic factors or the revelation of functions,
- a technological or planning approach, which analyzes the economic-technological background of effects.

According to the suggestion of H. Leser, (bio)ecology and geoecology are used as names for the distinction between first two approaches above and the disciplines connected with them. The distinction between these concepts lies in the judgement of the role of abiotic and biotic factors. Without underestimating the role and importance of biotic factors, it can be claimed that the abiotic geofactors determine the biotic adaptation.

In the last decades an intention is observed to approach the functioning of the natural environment and the investigation of abiotic factors by the use of geoecology. Meanwhile the problems of the structure and organization of the environment were solved by the methods of landscape ecology. Some authors do not distinguish between these concepts (Späth, H. J. 1976, Treppl, L. 1987, Wein, N. 1985). We hope that the following series of investigations call attention to the fact that these concepts are not rigid categories. For example, geoecology can be used for the study of structural features, while landscape ecology can give solutions to functional questions of the natural environment. The confrontation of the concepts of geoecology and landscape ecology seems meaningless from this point of view.

In our opinion, the distinction of geoecology from landscape ecology, which has undoubtedly more detailed content and traditional background, is reasonable by the following facts:

- questions connected with the functions of natural environment have come into prominence,
- the establishment of the partial potential of the natural environment,
- a special collection of data based on field measurement, and other more direct practical claims.

The German literature solves this problem mechanically. It claims that geoecology investigates the abiotic factors, while landscape ecology investigates the biotic and abiotic factors (Leser, H. 1986,1988). The English language literature solves this problem differently (Naveh, Z. 1984). The concept of geoecology was introduced into the technical literature by C. Troll (1971) who used the term synonymously with landscape ecology, but in other practical approaches it can be traced back to the works of C.O. Sauer et al. (1919).

In our view, geoecology can give answers to numerous geoscientific questions, such as the mitigation of natural and environmental hazards (e.g. waterlogging, floods, soil erosion) weighting of the effects of the changes in land use, and the evaluation of environmental impacts. In addition, geoecology can be the base of political decisions and regional planning if the decisionmakers take ecological data into consideration.

METHODS

In our view data are the most important in geoecology, since the assessment depends on the authenticity of the data. Therefore, we used the methods of the German geoecological mapping and field measurement in the mid 80's (Leser, H. 1984,1988, Richter, G. 1985). Geoecology investigates the functions and management of the natural environment. During geoecological mapping, normally primary sources of data become secondary importance, specifically the genetic and chronological factors. There are two innovations in our method which help us through the most critical points of mapping. On the one hand we used remote sensing data in the interpolation of simple data and on the other hand, we ensured the complexity of maps in such a manner that these geoecologic maps were divided into distinctive layers from a thematic point of view (e.g. physical properties of soils, DEM, etc.). These layers were stored in a GIS. The catchment area is the evident unit in the geoecological investigation.

In spite of the long history of geoecology and of geoecological mapping we cannot find existing geoecological maps in literature. The reason for this is that the functional connections investigated by geoecology are difficult to map. The structural patterns and their connections, namely the result of the ecology and landscape ecology, can be more easily mapped. Certain researchers envisage the geoecological map to be an overlay map, representing all of the abiotic factors simultaneously (Leser, H. 1986). In our opinion, the geoecologic map may appear similar to a virtual map. The geoecologic maps can be divided into three groups according to their degree of integration:

1. Analytic, analysing only one factor,
2. Complex, analysing more than one factor, or

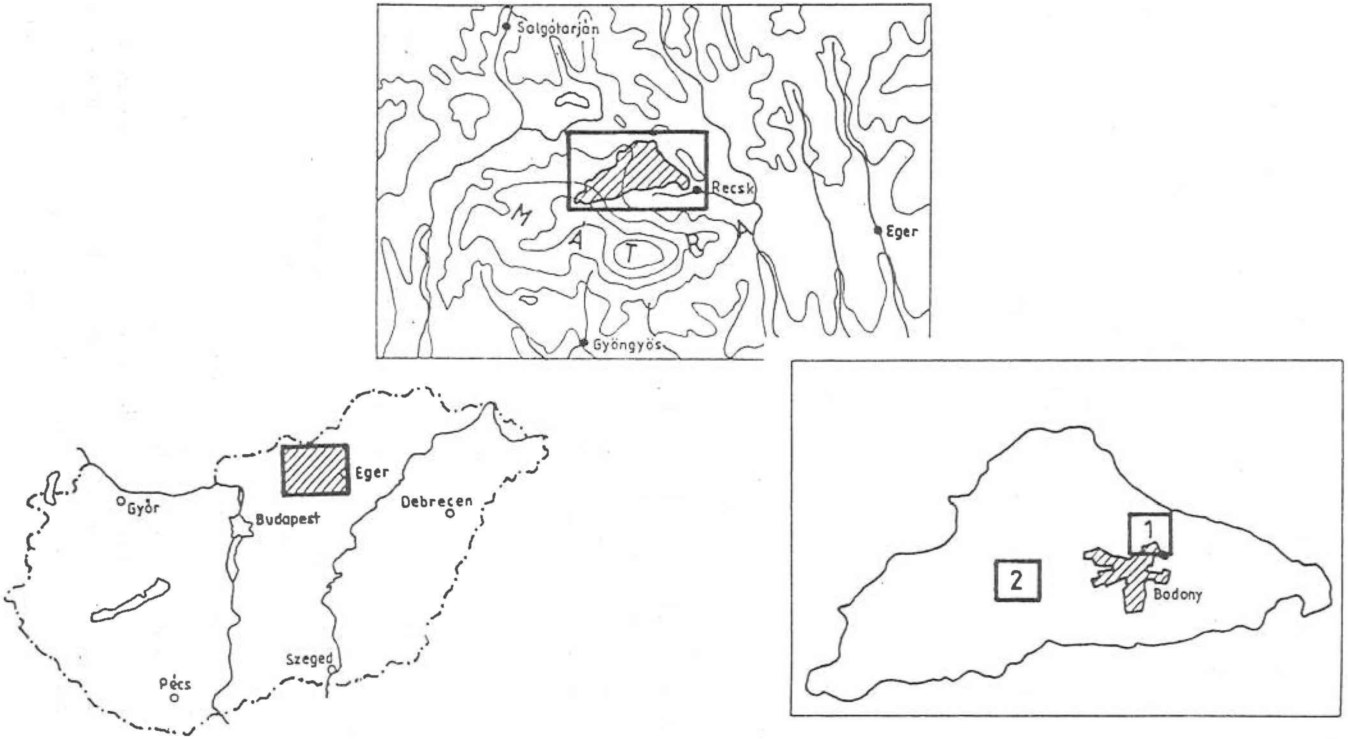

Figure 1 Location of the test sites in Hungary

3. Synthetic, combining multiple evaluations.

Naturally the geoecologic map is expected to satisfy the latter condition, but it may have other e.g. cadastral function.

In 1990 we started the geoecological mapping of various catchments. Longterm data series are necessary for exact analyses. Below we will attempt to answer those geographic questions which are answerable at the beginning of the investigation.

The catchment area of Katarét stream is situated in the Mátra mountains and is about 20 km^2 (see Fig.1). The relief, land use and rocks of the catchment are very diverse. We have chosen two characteristic test areas, 1 km^2 each. The first problem studied is in connection with the reclamation of partly cultivated surfaces and the development of the optimal land use. In the second part we analyze the effects of the environmental hazards, especially the areas endangered by soil erosion and the third one deals with recreation.

The maps were digitized using AutoCad and ArcInfo softwares and data processing was done by the GIS of ArcInfo and Idrisi.

RESULTS

1. We sought to answer the following questions: What kinds of foci can be found on the catchment area from which the natural vegetation can spread out again? Where and how can a better land use be designed in this area with respect to the geoecological conditions?

First, it was necessary to estimate the ecological stability of the present vegetation and to delimit those areas where we were able to coordinate the transition, considering the condition of the vegetation and the trend in its development. The potential corridors and barriers could be indicated which may influence the tendency of the transition. We analyzed the connections between the present, actual vegetation and the natural vegetation expected under the given geoecological conditions. In this way, we could identify areas where there was a major conflict between the present and the potential vegetation.

1.1. The investigation of a successions of plant associations gives important information about the trend in landscape development. The environmental factors control the rate of this development. The development of the succession can be divided into three phases: the initial phase (I), the optimal phase (II), and the degraded phase (III). The development is progressive from phase I to II and regressive from II to III.

We divided the plant associations into categories according to the values of the environmentally protected species (Simon T. 1988) living in the area (Fig.2). The points of the categories gave the catchment patterns. Since most of the area is under cultivation, the majority of the patterns belong to the third (degraded) phase.

The following associations fall in to this type: disturbed grassy association; clear-felling; cleared woodland; grassland; uncultivated field; acacia forest and a mixed forest with planted pine. The forests are situated between the optimal and the degraded patterns and their development may be either progressive or regressive. The initial plant associations appear as narrow ecological corridors between degraded and optimal associations. At present these areas are in the regressive phase. If human activity decreases in areas

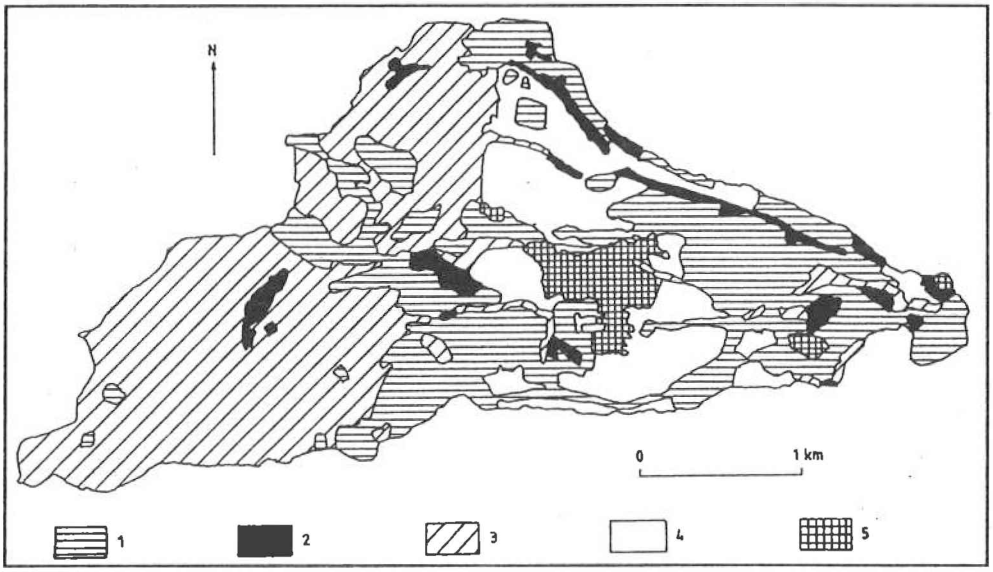

Figure 2 Series of plant assotiation in the catchment area
1 - degraded; 2 - initial; 3 - optimal; 4 - cultivated area; 5 - settlement

progressive development will be possible. The optimal (II) association is the oak-forest with hornbeam as well as submontane beeches situated on higher surfaces. We also consider the alderforest on the wet surfaces and grassy associations on slopes an optimal association. The pattern of the area shows that the former homogeneous biotopes of the plant associations were divided into smaller spots isolated from each other. This process is called "fragmentation" in ecology. Usually, fragmentation is unfavourable for the development of the living beings in a given area. We supposed that a fragment is optimal if the ratio of its area and its perimeter is favourable; at the same time this ratio indicates the stability of the association. Usually we can state that the earlier series of successions have smaller stability than that of the climax phase. But the stability may be high if successions promote a natural development. Instability is always the consequence of some kinds of interventions into the natural processes. The effects of these processes are inestimable.

1.2. We have calculated the ecological stability of the plants on the test sites. At first we used the following method. The stability of a given pattern is equal to the ratio of the area and the perimeter. But this number does not give a correct expression of pattern properties derived from its shape. If there are two patterns with the same shape, but different areas, the index of stability remains equal; conversely there may be two patterns with the same index of stability but with different shapes. Therefore, we had to find a new of index of stability. This new method is based on the elementary rules of geometry. The aim of this method is to express numerically the regularity or the irregularity of a pattern. The index of stability is the ratio of R_1 and R_2, where R_1 is the radius of a circle whose area is equal to the area of the given pattern, while R_2 is the radius of the circle whose perimeter is the same as the perimeter of the pattern.

$$\text{Index of stability } = \frac{R_1}{R_2} = \frac{\sqrt{4\pi T}}{K}$$

The R_1/R_2 ratio always ranges from 0 to 1 if we disregard any exceptionally deformed patterns. If the pattern is of circular shape the index of stability approaches 1 (for example the index of stability of a square equals 0.886).

1.3. If we compare the ecological stability and the calculated index of stability of a given pattern, then the plant associations can be divided into three groups. We can say that the plant association is unstable if its index ranges from 0 to 0.3, of medium stability if its index ranges from 0.3 to 0.6, and stable if its index is higher than 0.6.

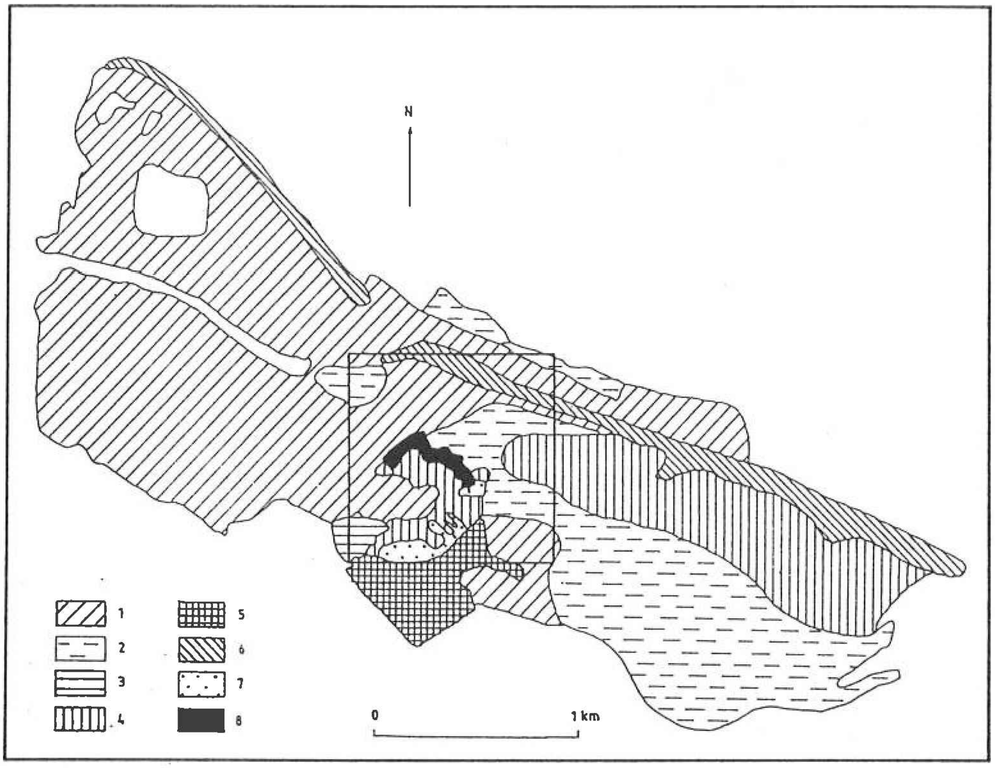

Figure 3 Plant associations on test site No.1 (near Bodony)
1 - cultivated area; 2 - pasture; 3 - mixed forest (pine); 4 - meadow, grassland; 5 -settlement; 6 - hydrophyte assciation; 7 - orchard; 8 - acacia grove

On the first investigated test site (Fig. 1, No. 1), the forest association and the meadow-grassland are the most stable plant associations (Fig.3). On the cultivated surfaces, e.g orchards, the index of stability is lower (regressive development). Especially the pastures have a high index which are the continuations of stream-bank successions. The junction of the ecological corridors with these areas (beside reducing agricultural lands) makes the advance of the ancient succession of meadow possible. But this process can become progressive if the area of cultivated land decreases. The index of stability of the cultivated areas ranges from 0.2 to 0.5. If we examine the index of stability on the land use map it can be claimed that the forests, row plants and graincrops have high indices (higher than 0.6). It is to be noted that these data are relative and they cannot be compared with the index of stability of the plant associations because the natural conditions have been changed by human activity.

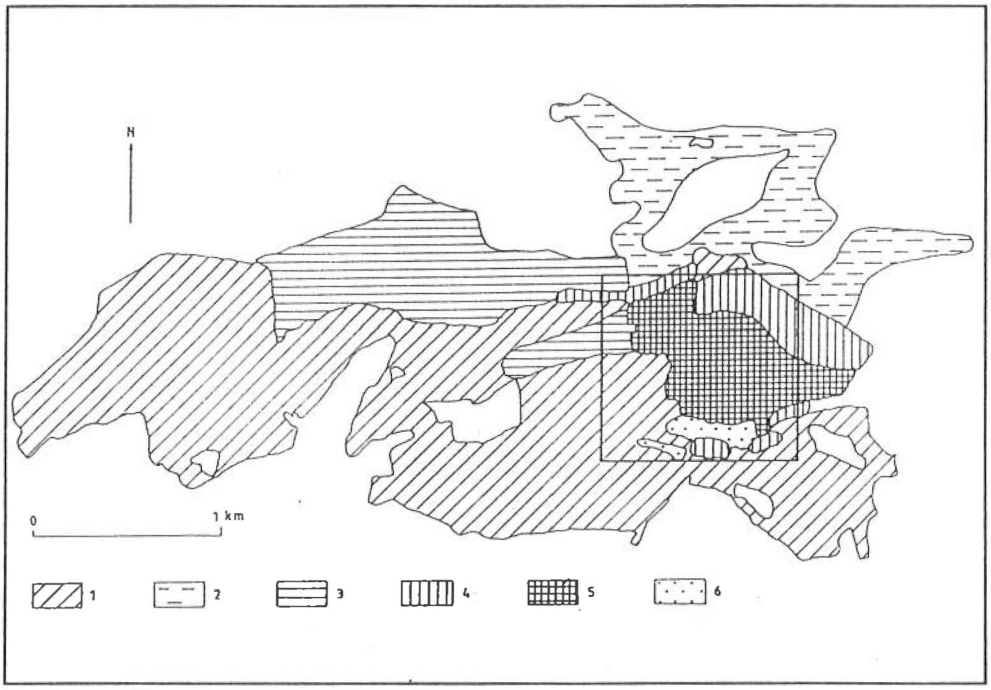

Figure 4 Plant assotiations on the test site No. 2 (Kecske-hill)
1 - oak forest with hornbeam; 2 - hydrophyte association; 3 - mixed forest (pine); 4 - meadow, grassland; 5 - acacia grove; 6 - mixed decidous forest

On the other test site (Fig. 4), there is a high index of stability for the following plant associations: mixed broad-leaved forest, meadow, grassland and bushes. The test site is situated at the interface where the natural association is disturbed by planted vegetation (e.g. acacia grove). The geometric properties of the artificially planted vegetation have not yet changed basically, but the index of stability of the mixed broad-leaved forest and the oak hornbeam forest is high enough. On one big pattern, the meadow-grassland indicates the advance of natural vegetation (high index of stability, greater than 0.7).

On this test site, progressive development can be revealed in comparison to the former test site. The progressive development leads to the increase of stability of the plant association. The succession of the plant association develops from the meadow (initial phase) to the optimal association. The index of land use better represents the reality since in all but one case it is lower.

Collectively the areal differences in index of stability are synchronous with the above presented deviations in the development of the succession.

1.4. It is known that species have welldefined ecological demands, e.g. water budget of the surface (W), soil reaction (R), nitrogen-content of the soil (N) and temperature (T). The average values of these factors for a given group of plants are known (16). Usually the value of a factor ranges from 0 to 5 (or 10). During our investigation we substituted the W factor with soil texture, the R factor with the pH value of soil, the N factor with thickness of humus layer and the T factor with aspect. We evaluated the measured real geoecological conditions and the geoecological conditions which are claimed by the plant associations found on the test sites. According to literature the common value of the W and R factors occurs with a weight of 2/3 and the value of the N and T factors with 1/3. The possible directions of the development can be estimated by the help of the above mentioned method (ef. 1.3.). Our results are presented in Fig. 5. (data refer to test site No. 2, which is mainly covered by natural vegetation).

	1	2	3 /value/
W	clay	sand	loam
R	4.5-5.5	7.2-8.5	5.5-6.8 pH
N	<60	60-100	>100 cm
T	northern	flat	southern

The natural plant association on the area is the oak forest with hornbeam trees. Bigger patterns occur under favourable conditions if we look at the true geoecological conditions (2223). Here the true condition is the same as the ecological requirement of the plant association. On the smaller isolated area, the value of the W factor is lower and the clay content increases in the soil. The development of the succession is regressive and the index of stability is of medium value. At the mixed broad-leaved forest, there are lower real conditions (1133 or 1223) on significant lands than the ecological demand of the association. The index of stability is very low. Here we can find the degraded (III) phase and the development is regressive.

The development can be progressive in the acacia groves, because the real conditions (2333, 2332) are very favourable for the natural vegetation and at the same time the requirement of the acacia grove is very low. We can say that the new direction of the coordinated development may tend toward this area. The gallery acacia groves are

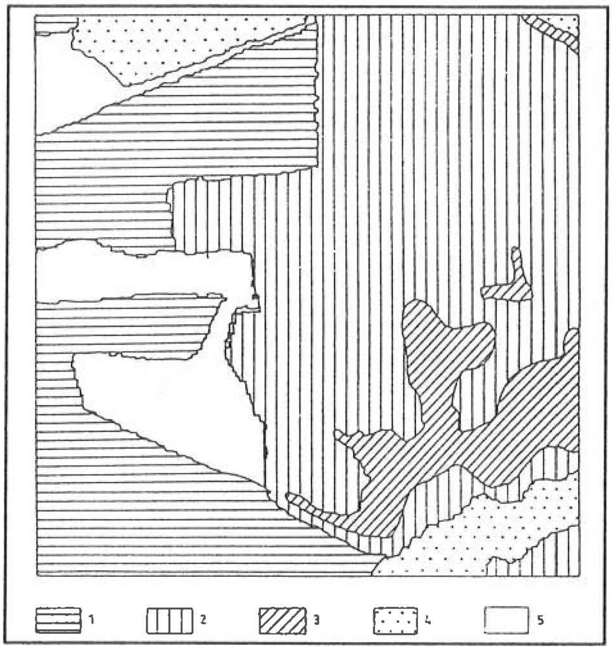

Figure 5 The map of the goeecological conditions of test site No. 2 (Kecske-hill)
1 - 1321-1331; 2 - 2332-2333; 3 - 2223-2211;
4 - 3321-3213; 5 - 1133-1211

especially favoured by these geoecological conditions, but in the closed acacia groves, the soil reaction demand and the true soil pH harmonize while the physical properties and the W factor do not. It is the result of uncontrolled planting.

The meadow and grassland are situated on favourable lands (3321), and their indices of stability are high and the true conditions are in accordance with the ecological requirements. The development is progressive and the association develops from the initial phase (I) to the optimal association (II). This process can be sustainable if human activity decreases. The plants species on the meadows and grasslands are euryecious plants; therefore, the direction of development is favourable and the index of stability is also high.

It can be claimed that on the test site there can be simultaneous progressive and regressive developments which can be in equilibrium with proper land use in future.

1.5. In our opinion, the investigation of the landscape budget for entire catchment could be very instructive and the identification of the surfaces of energy and the material loss. We can simply map areas with negative, positive and neutral budgets (from a soil scientific and hydrological point of view). We calculated the energy as a function of relief, solar radiation and aspect (Kerényi A. 1977, Mezősi G. 1985). We would like to present one of the possible combinations of conditions in the following section.

2. One of the most important aims of geoecological mapping is the forecasting of natural hazards. Here we present the analysis of those surfaces which are endangered by soil erosion. We completed this calculation for the whole catchment. The method is based on the Universal Soil Loss Equation (USLE) (Wischmeier, W.H. - Smith, D.D. 1978) as well as on the modification of this equation by Schmidt (Schmidt, R.G. 1988). The aim of the modification is to substitute those factors, which can be defined by experimental methods, with measurable values (e.g. K, i.e. soil erodibility factor). Therefore, the more important

components of this method are the soil-type, slope, precipitation during the growing season and land use as well as other modifying factors (e.g. humus content of the soil, vertical and horizontal slope shape etc.).

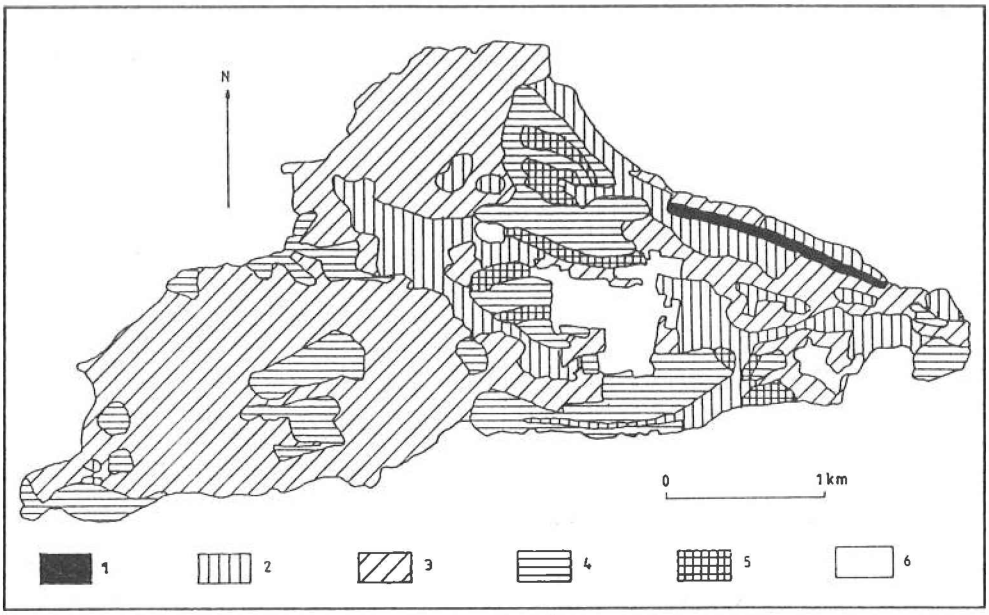

Figure 6 Map of soil erosion on the catchment (t/ha/year)
1 - <1; 2 - 1-5; 3 - 5-10; 4 - 10-15; 5 - 15-30; 6 - settlement

Different tables help us to apply the method (Fig.6). If the plant cover is stable, soil erosion does not reach a value of 10-15 t/ha/y, while on cultivated land soil erosion is always higher (25-30 t/ha/year). The reason for soil erosion on the first test site is the physical and genetic properties of the soils while on the other test site it is the angle of slope.

3. Because of the increasing recreational use of the catchment area, the estimation of the physical carrying capacity is a very important task. This method is based on that fact that the soil can be favourable for characterisation of climate, rocks, relief and vegetation. In the USLE we substitute T for A, the value of the combined cover and erosion-control factors (CP) necessary to maintain the productivity of the soil is: CP=T/RKLS . The P factor approaches 1.0, consequently the P factor was omitted from the equation in its adaptation for outdoor recreation planning (Kuss, F.R. - Morgan III, J.M. 1986). Thus the equation becomes: C=T/RKLS. The product is a measure of the erosion potential of each soil, assuming barren soils. According to the empirical data, if the value of C ranges from

80-100%, the physical carrying capacity of the given area is low (60-80 % - medium, below 60 % -high capacity).

On the test sites there are areas with medium and high carrying capacities and their greater part belongs to the group of closed grassy associations. We hardly find natural lands of high physical carrying capacity, but the forests are of medium carrying capacity. The reason for this is that the forests are very sensible associations and forested lands showed high angles of slope.

SUMMARY

From the first results of the geoecological mapping on the given area, we can say that geoecological investigation is suitable for the estimation of the physical carrying capacity of the test site. We are able to estimate the development of the land (ecological processes, changes in plant associations etc.). This method helps to coordinate land use and recreation.

REFERENCES

Kerényi, A. (1977):Különböző reliefenergia-ábrázolások és az erózió kapcsolata a tokaji Kopasz-hegy példáján. Földrajzi Értesítő 26. pp. 289-3O4.

Kuss, F.R. - Morgan III, J.M. (1986):A first Alternative for Estimating the Physical Carrying Capacities of Natural Areas for Recreation. Environmental Management, Vol. 1O, No. 2, pp. 255-262.

Leser, H. (1984):Zum Ökologie-, Ökosystem- und Ökobegriff. Natur und Landschaft. 59. pp.351-357.

Leser, H. (1986):A geoökológiai tájszerkezetkutatás problémái. Gondolatok a bázeli koncepció nézőpontjából. Földrajzi Értesítő. 35. pp. 1-15.

Leser, H. - Klink, H.J.(1988):Handbuch und Kartieranleitung Geoökologische Karte 1:25000 (KA GÖK 25). Trier, p.349

Mezősi, G. (1985):Természeti környezet potenciáljának felmérése a Sajó-Bódva-köze példáján. Elmélet-Módszer-Gyakorlat 37. Budapest, p.216.

Naveh, Z. - Liebman, A.S.(1984):Landscape Ecology: Theory and Applications. New York:Springer Verlag

Richter, G. (1985):Naturraumpotential und Raumgliederung-Überlegungen zu Aufgaben eines Arbeitskreises. Berichte zur Deutschen Landeskunde. 59. Trier, pp.257-265.

Sauer, C.O. et al. (1916):Starved Rock State Park and its Environment. (Chicago, Univ. of Chicago Press. Bull. of the Geogr. Soc. No.6.

Schmidt, R.G. (1988):Methodische Überlegungen zu einem Verfahren zur Abschätzung des Widerstandes gegen Wassererosion. Regio Basiliensis, XXIX.1-2. pp.111-121.

Simon, T. (1988):Nature conservation ranks of Hungarian vascular flora. Abstacta Botanika. XII. pp. 1-3.

Späth, H.J. (1976):Geoökologische Praktikum. Paderborn, p.211.

Treppl, L. (1987):Geschichte der Ökologie:vom 17.Jahrhundert bis zur Gegenwart. Frankfurt, p.165.
Troll, C. (1971):Landscape ecology (geo-ecology) and bio-ceonology a terminology study. Geoforum 8. pp. 43-46.
Wein, N. (1985):Geoökologie und Umweltprobleme.Materiellen zur Geographie.Frankfurt am Main, p. 173.
Wischmeier, W.H. - Smith, D.D. (1978):Predicting rainfall erosion losses - a guide to conservation planning. USDA, Agriculture Handbook. No. 537. p.58.
Zólyomi, B. et al. (1967):Einreichung von 14OO Arten der ungarischen Flora in ökologischen Gruppen nach TWR-Zahlen. Fragmenta Botanica. 4. pp.1O1-142.

University of Szeged, Department of Physical Geography
Egyetem str. 2-6. PB. 653
H-6722 SZEGED
HUNGARY